

Human-Agent Teamwork in Collaborative Virtual Environments (Doctoral Consortium)

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ABSTRACT

The growing interest in using Collaborative Virtual Environments (CVEs) increases the need to create heterogeneous teams comprised of humans and Intelligent Virtual Agents (IVAs). The main aim of my PhD is to study the factors that tend to improve team performance and foster collaboration between humans and IVAs in CVEs. To reach this aim, a framework, namely MACVILLE, was designed for multi-agent collaborative virtual learning environment based on Activity Theory was proposed. In addition, an agent architecture integrated with a human-agent teamwork communication model, namely HAT-COM, was developed. Three experiments were conducted to investigate: a) the impact of multimodal communication, verbal and nonverbal, on the development of a Shared Mental Model (SMM), task-based and team-based, between humans and IVAs; b) the effect of the development of a SMM on human-IVA team performance; c) criteria that are likely to break the developed SMM in human-IVA teams.

Categories and Subject Descriptors

I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—*intelligent agents, multi-agent systems.*

Keywords

Human-Agent Collaboration, Shared Mental Model, Verbal Communication, Non-verbal Communication, Team Performance.

1. INTRODUCTION

This PhD project investigates how an Intelligent Virtual Agent (IVA) can be an effective team member with a human in the context of a Collaborative Virtual Environments (CVEs) that provides the parties with virtual objects and a shared place in which they can interact together. CVEs have been used as a mediation tool to facilitate human-human collaboration across disparate spaces. Moreover, the concept of CVE includes the collaboration between human participants and virtual entities such as IVAs. IVAs refer to humanoid virtual entities that simulate humans in their abilities and characteristics.

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The thesis discussed in this paper aims to study the factors that have been found to affect human teamwork to apply them to human-IVA teamwork. These factors include the existence of effective multimodal communication and a Shared Mental Model (SMM). SMM is the state among team members where they have overlapping knowledge and belief. The idea behind SMM is that the overall performance of teams improves if team members have shared knowledge about the team and knowledge about the task [1]. SMM was introduced by in the context of teamwork amongst humans. Later, it became apparent that SMM is not only important in human teams, but also in human-agent teams [9]. Many researchers who have been studying SMM classified the shared knowledge into two categories: knowledge about the team and knowledge about the task [1].

Another factor we studied was multimodal communication. Communication is considered a crucial factor in successful teamwork. According to some research work, computer-mediated communication does not differ from face-to-face communication in terms of the capability of social information exchange.

2. MOTIVATION

A number of research gaps and challenges motivated the current PhD study, including:

- Increasing interest to use CVEs to support task-based collaboration between humans and IVAs.
- CVEs need to run in real-time and development of believable IVAs able to respond and adapt accordingly is challenging.
- Human-Machine interaction is a challenge, particularly communication [8]. While some studies explored human-IVA communication; few address two-way multimodal human-IVA communication in CVEs.
- Establishment of a SMM in human-agent team work is the biggest challenge [10]. Very limited research has studied the development of a SMM between IVAs and humans. Moreover, to the best of our knowledge, there is no study that investigated the impact of multimodal communication techniques between a human and an IVA on the development of a SMM.

The research project reported in this paper seeks to address these challenges and gaps. That is to say, the research aims to verify the factors that tend to foster collaboration between humans and IVAs in CVEs. After reviewing the literature, two main factors were identified, namely multimodal communication and SMM. Further related factors, such as personality, could be included to make human-IVA collaboration smoother.

3. PHD CONTRIBUTION

The main aim of my PhD is to study the factors that develop collaboration between human and IVA in CVE. Figure 1 depicts the factors being explored in this study to determine their impact on IVA-Human collaboration in a CVE.

Initially, to understand the requirements of human-IVA collaboration in VE, we presented the design of a framework [4], called MACVILLE, for a multi-agent collaborative virtual learning environment based on Activity Theory [2]. The MACVILLE framework indicated the importance of communication for collaboration in the VE. In addition, the research paper demonstrated the need to extend the design of an IVA to include collaborative and social abilities. This extension was addressed in [3] where we presented an overview of existing research work on collaborative agents in virtual environments and proposed an agent architecture that handles two-way human-agent collaboration.

Based on the outcomes of [3] and [4] and the paucity of research studying human-IVA communication in CVEs, we presented a communication model for human-agent teamwork communication called HAT-COM [5]. HAT-CoM was implemented and integrated into agent architecture presented in [3]. A study was conducted with 66 undergraduate students. Previous research work focused on agent-to-agent communication or human-to-agent communication in a role-specific static environment. Our presented model included two types of communication verbal and non-verbal.

To evaluate the impact of our proposed human-agent communication model, i.e. HAT-CoM, on developing/breaking SMM between a human and an agent, a second study was conducted [7]. Data was collected using two techniques: post-session survey and user tracking in log files. The collected data was evaluated analytically and inductively. The analytical evaluation of survey data aims at investigating the impact of HAT-CoM components, i.e. verbal and non-verbal, on the development of SMM features, i.e. knowledge about the task and the team. The inductive evaluation of log files aims at verifying the development of SMM via HAT-CoM through tracking the changes in the designated outcomes of SMM.

To weave all the threads together, a third study was carried out, in [6], to investigate the impact of human-IVA multimodal communication and SMM on one hand, and human-IVA team performance on the other hand.

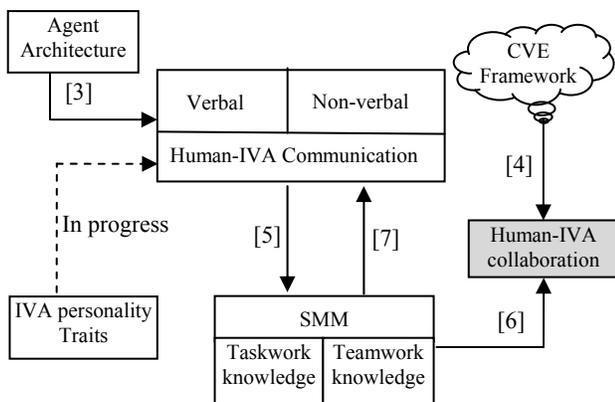


Figure 1. The structure of the discussed PhD to study human-IVA collaboration

4. FUTURE WORK

Future work will take into account that humans have different personality traits that directly affect their verbal and non-verbal communication and the way they form teams. This work will take two directions: (a) to design/implement a CVE inhabited by IVAs with different personality traits as shown in their verbal and non-verbal communication techniques, (b) to investigate the impact of (mis)match between the personalities of humans and IVAs on the development of a SMM and consequently on team performance.

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